"SOME PECULIARITIES OF MAIZE IN ASIA" BY N. N. KULESHOV

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Illustrations re-drawn from the published photographs by Ellen Kern Lissant

TRANSLATORS' NOTE: The following is a translation from the Russian of a paper by N. N. Kuleshov (Bull. Appl. Bot., Genet., and Pl. Breed. 19:325–374. 1928. English summary, pp. 370–374). It is of particular interest in view of recent findings concerning the geography of races of maize. The only extensive studies of maize in the Orient are here described by the author. Kuleshov's entire work has been translated and included with the exception of his literature review of the American studies of waxy maize.

The English used in this translation will strike a number of people as being quite repetitive and wordy. For instance, the word *obraztsy*, which we have translated *collections*, appeared again and again. This characteristic, along with the redundant phrases and wordiness, has been retained wherever the meaning was sufficiently clear. We have attempted to retain in English something of the quality of the Russian original.

Regarding the references missing from the *Literature Cited*, we should mention in fairness to Dr. Kuleshov that there are innumerable evidences of careless editing.

In the work of the American investigators, G. N. Collins and J. H. Kempton, one meets an array of very interesting characters and attributes which are unknown in maize from the American continent but which were discovered in collections of maize from Asia.

During the years 1926 and 1927, relatively vast amounts of material [data] concerning the maize of Asia passed through the All-Union Institute of Applied Botany, being composed of both laboratory and field studies. From this material it was possible to expand the observations of Collins and Kempton and to establish an array of new peculiarities in the maizes of Asia which are unknown to the American investigators.

Since we are planning a future publication of the complete work on Asian maize, in the present preliminary communication we will briefly bring out only the most interesting of the facts which have been established.

All the material which has been studied up to the present time is listed in the following table, and consists of collections from different regions of Asia and Transcaucasia:

1. Asia Minor ..... 65 collections
2. Persia ..... 10 collections
3. Afghanistan ..... 24 collections
4. Turkestan ..... 65 collections
5. The Primorskiĭ [Maritime] Province ..... 85 collections
6. Manchuria ..... 51 collections
7. Western China ..... 18 collections
8. Japan ..... 5 collections
9. India, Ceylon, Java ..... 6 collections
10. Armenia ..... 59 collections
11. Azerbaijan ..... 10 collections

We will first pause to refer to the American work, passing thereafter to the data of our investigations.

I. The Data of the Americans' Concerning the Maize of Asia

[Omitted]

II. Our Own Investigations on the Maize of Asia

1. WAXY MAIZE

In the collection of maize which is located at the All-Union Institute of Applied Botany and New Crops, the presence of the type *waxy* was established in several cases.

(1) Of two collections received from the expedition of V. V. Markovich to Shanghai, one collection (on the cob) was white with a single blue kernel. The other (shelled corn) was called "Buo Rew" and contained a mixture of flinty, tooth-like yellow kernels along with an admixture of a single grain of the waxy type which had a light yellow color. Both collections were received in 1927.

(2) Four collections were received by the Institute from the experiment Station "Eho" in northern Manchuria, and in all four the waxy kernels have a yellow color of varying intensity. For two collections, the source was not designated, but for two it is known: Maize no. 136 "Nyan-pao-mi" ("sticky") from Ninguta, and maize no. 137 "Nyan-pao-mi" from Tubin. Both of these localities are in northern Manchuria.

(3) Two collections were received from the Primorskiĭ Experiment Station. Their source was the village of Lukyanovka in the Utkin district, the Spassk territory of the Primorskiĭ [Maritime] Province. One collection, no. 59, consists only of waxy maize of a light yellow color, which indicates that this sort has been cultivated here for more than twenty years. The second collection, no. 57, is principally flinty, but as an admixture it has a single kernel of the waxy type.

A comparison of all the collections listed above with the original collection received from Collins confirmed their undoubted classification as the waxy type.

We pause to consider the meaning of these findings. The collections from the region of Shanghai, received from V. V. Markovich, confirm once more the fact, which is known from the American literature, that waxy maize was discovered

Fig. 1. Plant of waxy maize, from Collins (1909).

and cultivated in this region. The collections from Ninguta and Tubin, which were sent by the Eho Station, establish a new place of discovery of waxy maize, which is significantly different from those three regions (Shanghai, Burma, and the Philippines) in which this maize was previously known.

In the seed catalogue of the Eho Experiment Station, these collections are filed under the name "Flint Corn, that is, flinty maize", but are labelled with the Russian name "Kleikaya" (sticky), and also the Chinese name "Nien-pao-mih". This Chinese name is differentiated from the other Chinese names "Pai-pao-mih", "Hei-pao-mih", and "Huang-pao-mih". There are, in the catalogue of the Eho Station, other cultures of flinty maize which force the supposition that the local populace differentiates this sort of maize from the ordinary flinty maize[1]

The collections from the village of Lukyanovka, which is located approximately 300 kilometers east of Ninguta in the direction of Vladivostok, may be assumed to have a common origin with the waxy maize which is cultivated in Ninguta. None-the-less, on the basis of their being found here, we have sufficient grounds to assume that the growing of maize of the waxy type in this northern region of eastern Asia is wide-spread and is not especially rare.

If we now compare our apparently new discovery of waxy maize with what was previously known concerning its cultivation, we obtain the following: the Philippine Islands[2] are located at 5–15° north latitude; the upper Burma regions, 23–26° n. lat.; the Shanghai region, 31–32° n. lat.; the village of Lukyanovka, 43° n. lat.; Ninguta, 45° n. lat. Thus, at the present time, the area of diffusion of waxy maize has extended great distances from north to south, having been discovered in 1908 at Shanghai, again in 1915 in upper Burma, and 1920 in the Philippines. With our discovery [known] waxy maize immediately moves far to the north. This finding permits us to hypothesize about the limits of diffusion of this type in eastern Asia, but the incompleteness of maize investigations in this territory does not permit us to speak with certainty.

The matter of the extent of the limits of cultivation of waxy maize westward is of great interest. We have, unfortunately, insufficient material with which to trace the spread completely and clearly. At any rate, our material permits us to say with certainty that there is no waxy maize in central Asia or in Asia Minor. Turkestan was covered by us completely and in detail, from the China border to the Caspian Sea. Afghanistan was thoroughly explored by N. I. Vavilov, while P. M. Zhuzovskiĭ travelled for two years in Asia Minor, and in neither place was waxy maize discovered. In 1927 we received eighteen collections of maize which were collected in western China from our consul in Kashgar, in none of which was there waxy maize. We have not yet spoken of the collections from the Caucasus and European areas. Here, of course, *waxy* does not occur.

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[1] The list of available seed at the Eho Station for exchange with other experiment stations. K. V. Zh. D., Harbin, 1926.

[2] These localities are those mentioned in the omitted review of American literature.

Fig. 2. Typical brachytic maize (from Kempton, 1921).

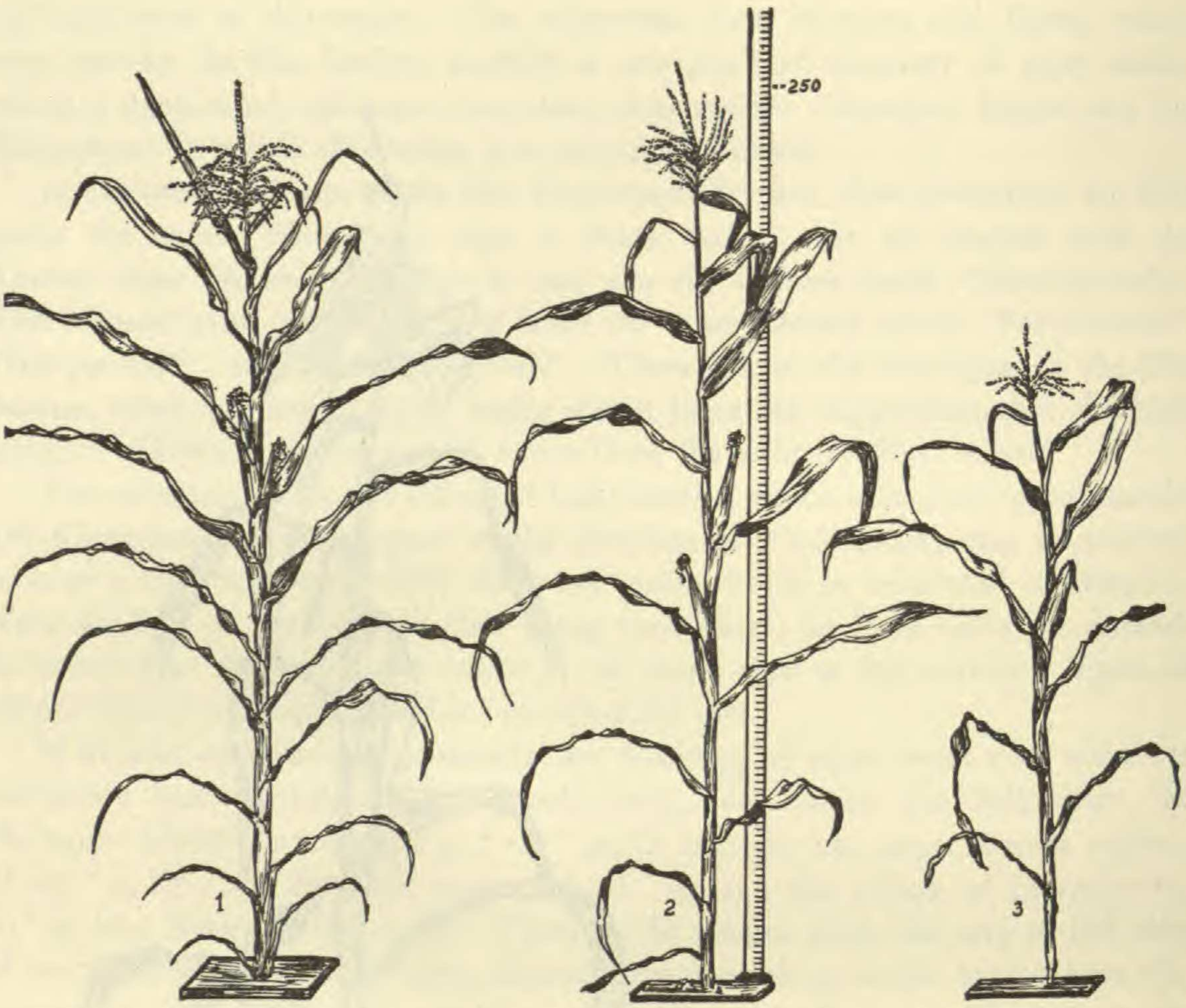

Fig. 3. The most widespread types of maize plants from Manchuria and western China, grown in Kharkov, 1927. Plants like Nos. 2 and 3 are more frequent in Manchuria.

In 1926 and 1927 we were fortunate enough to receive exceptionally interesting material from America. The expedition of S. M. Bukasov, of U. N. Voronov, and of S. V. Usepchuk brought us specimens of maize from Mexico, Guatemala, Panama, the island of Cuba, Venezuela, Colombia, Peru, and Bolivia. Approximately 2,000 collections were sent in all, representing a remarkably unusual variety of types. And here, in the principal center of variation from which maize originated, we, repeating the experiment of Collins,[3] did not find maize of the type *waxy*. Thus, this particular type of maize is, apparently, peculiar to eastern Asia.

Since we already had in our collections samples of waxy maize, we planted them in 1927 and observed differences in their vegetative character. The majority of plants in collections from Shanghai had the attributes which were described by Collins: stiff leaf blades, silking ears hidden by the leaf sheaths, and the upper leaves displaced to one side and covering the panicle. The collections from Ninguta and Tubin were very singular in aspect, being thin-stalked plants with absolutely no tendency to produce lateral shoots. It is possible, however, that the conditions

[3] Apparently the testing of kernels for the presence of waxy endosperm.

in Kharkov in 1927 contributed greatly to this situation, causing a small number of leaves and well-exserted panicles to be produced. This aspect was not peculiar to these collections only; similar plants predominated in all of the numerous Manchurian collections of flinty maize. Figure 3 depicts plants which are characteristic of the collections from Manchuria. For the most part, one encounters plants II and III, plant I being particularly rare.

A collection of waxy maize from the Primorskiĭ Province was very extraordinary in its vegetative appearance and the make-up of its plants. All individuals were predominantly of the Manchurian type but among them were many plants similar to those we have termed the "European type". The latter is distinguished by stalks of average vigor which produce one to two lateral stalks similar in degree of development to their main stalk under favorable conditions, as is characteristic of the European flints. In individual plants one could observe attributes described by Collins for Shanghai maize: assymetrical upper leaves which are straight and which cover the silking ears in their axils at the time pollen is shed (fig. 4).

TABLE II*

PHENOLOGICAL OBSERVATIONS ON SAMPLES OF WAXY MAIZE

	Date seeded	Date of shoot emergence	Date of pollination	Date of silking	Date of ripening	Plant height	Number of leaves
Shanghai from Markovich	5/12	5/28	8/25	8/27	.....	.....	20.7
Ninguta	5/12	5/28	7/23	7/22	9/12	207	17
Primorskiĭ Province	5/12	5/28	7/19	7/23	9/12	188	17

*Table I is not included, since it was reprinted from Kempton (1921) in the omitted part of this paper and was not referred to elsewhere.

The data from phenological observations and measurements are presented in table II, representing individuals of the waxy type cultivated by us in Kharkov. Unfortunately, we were unable to compare them with Collins' plants from Shanghai, due to the fact that the seed of the latter had become inviable since its receipt at the Institute in 1923. The data in this table demonstrate that the Shanghai collections of V. V. Markovich were very late under Kharkov conditions, commencing flowering on August 25, and failing to ripen before the first killing frost on October 15. The collections from Ninguta and the Primorskiĭ Province were very similar to one another and should be classed as early in maturity. The Shanghai collection is distinguished also from the other two by its large number of leaves.

In the collections from Ninguta it is interesting to note that the silks appear before pollen is shed. The plant height of the collection from Ninguta also indicates its dwarfness.

Fig. 4. Diversity of plants of waxy maize from the Primorskiĭ Province, grown in Kharkov, 1927.

The above remarks on the vegetative peculiarities of our collections of waxy maize indicate that only the Shanghai collection was similar to that described by Collins in his first paper (1909). The Primorskiĭ collection was similar in vegetative characters to the collections of flinty maize of that region. The Primorskiĭ collection reflects the influence of the Manchurian type, on one hand, and the European, on the other. The latter has a wide distribution in the Primorskiĭ Province, to which it had been brought by the Ukrainian settlers. A mere trace of the Shanghai type is retained by these plants. This fact is merely given and causes no surprise, since from the work of Collins we know that the endosperm factor *waxy* in his investigations was not linked with the vegetative attributes of the plant. However, such being the case, that in northern Manchuria waxy maize steadily acquires the aspect peculiar to most of the maize in this region, this observation attests to the fact that here waxy maize is not a newcomer.

Due to a misunderstanding, waxy maize has not yet received a generally accepted scientific Latin name, and different authors vary in referring to it. Americans usually use the term *waxy* but sometimes use the term *Chinese*, while German authors use *wachsig* or *chinesische*, etc. Since waxy maize of the average group as distinguished by Sturtevant occupies a special place, we suggest the Latin name *Zea mays ceratina* Kuleshov (spec. nov.).

2. THE PERSIAN TYPE OF MAIZE

In 1926, a large number of collections of maize were brought to two points, Kharkov and Sukhum. Almost the entire world was represented and the number of collections which were planted at both these two points approached 1,500. On the basis of the enormous amount of vegetative diversity in the collection, the Persian plants were sharply differentiated by their short height and the general condensation of the plant structures, as were those collections from the regions of middle Asia and Transcaucasia which border Persia.

These collections were again grown in 1927, and the peculiarity of the above specimens was again sharply distinguished from the variety of the world-wide collection, in spite of the exceptionally favorable conditions during the growing season. The 1927 study of these collections demonstrates that, besides shortness, the plants possessed an array of other extremely interesting peculiarities. The peculiarity [probably shortness] was expressed by all collections from Persia which were studied, so we therefore termed this completely different appearance of maize plant the Persian type.

Let us now turn our attention to the characteristics of the collections in which the manifestations of the Persian type may be observed. Persia was represented in our seedlings by seven collections from Seistan and Zurabad, all of which were distinguished by the following characters: (1) shortness of the plants; (2) coarse, wide, and short leaves with stiff blades; (3) definite waviness of the leaf blades; (4) the poor exsertion of the panicle which is covered by the stiff upper leaves; (5) the non-emergence of the silking ears at tasseling; (6) the correlation of the blooming of the male and female inflorescences, frequently developing protogyny. Figure 5 shows many of these characters very well. One may observe the shortness of the plants, the stiffness of the leaf blades and the waviness of their surfaces, the manner in which the stiff upper leaves cover the panicle, and the nearly-hidden silks of the plants in the leaf axils, illustrated under a higher magnification in fig. 6.

While closely related in the majority of these characters, several Persian collections were distinguished by their capacity to produce lateral shoots. Of seven collections grown in the field, five were characterized by an almost complete lack of the capacity to produce lateral shoots both years, whereas two collections expressed this capacity rather strongly. We must needs note, however, that the plants at the edges of the plots were observed to be surprisingly uniform in appearance. Figure 7 shows the vegetative appearance of the plants of the collections from Persia. The plant on the extreme right represents the striking bushiness of the Persian type plants.

The above photographs [illustrations] doubtless have shown the peculiarities of the plants which we have distinguished as the Persian type. However, for a more complete picture, we present several measurements of plants of the Persian type for comparison with measurements of the prevailing sorts, Minnesota 13 *(indentata)*, and Longfellow *(indurata)*, as well as the original *brachytic*, which was received by us through N. I. Vavilov from Emerson of North America. As

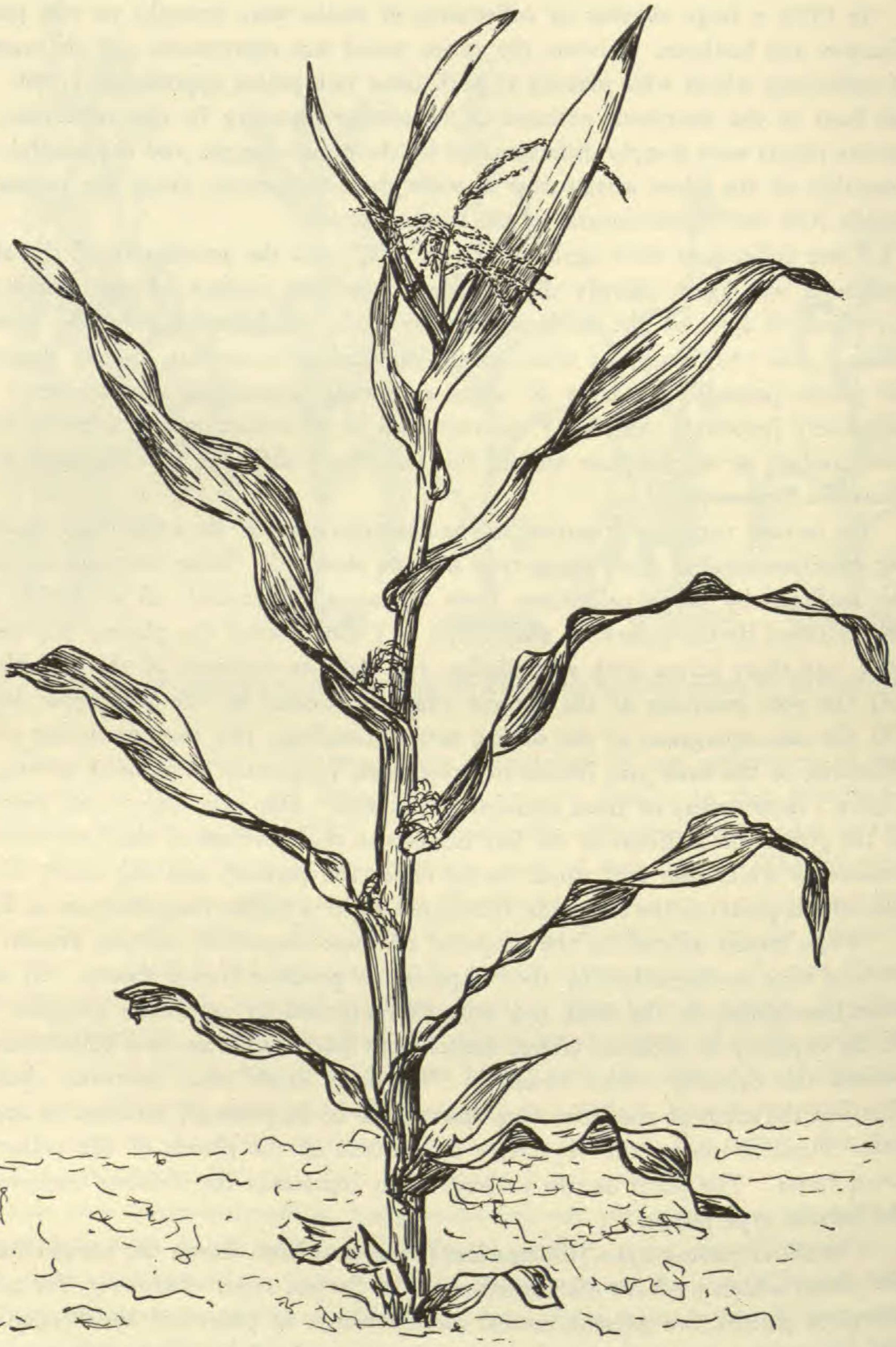

Fig. 5. Typical plant of Persian maize, grown in Sukhum, 1927.

indicated, the growing conditions during the seasons of 1926 and 1927 were very different, 1927 being much more favorable and producing more vigorous development of the plants. But since Minnesota 13 and Longfellow were sown both years, an opportunity for a comparison [of the plants in both seasons] still remains. *Brachytic* was sown only in 1927.

TABLE III

OBSERVATIONS ON MAIZE PLANTS IN 1926 AND 1927 (KHARKOV)

Name	Origin	Plant height		Number of leaves on main stem		Stem thickness		Number of stems		Panicle exsertion		Number ears per plant	
		'26	'27	'26	'27	'26	'27	'26	'27	'26	'27	'26	'27
Persian 1701	Zurabad	94	104	.....	16.3	.....	1.9	1.0	1.0	0.4	2.0	1.0	2.0
Persian 1702	Zurabad	92	116	17.2	17.4	.....	1.7	1.1	1.2	0.3	1.2	1.6	3.1
Persian 1698	Seistan	96	142	18.8	18.5	.....	....	1.6	2.3	0.6	3.0	2.9	6.3
Brachytic	Emerson	.....	118	.....	24.0	.....	2.4	....	1.0	....	1.0	....	1.0
Minne. 13	U. S.	147	211	15.4	16.0	.....	1.7	1.0	1.4	5.8	7.5	1.0	1.4
Longfellow	U. S.	140	229	14.8	16.5	.....	2.2	3.6	4.4	....	6.7	1.1	1.6

Let us view the data from the table (Table III). The shortness of the Persian type plants, in comparison with the other collections, is shown perfectly clearly. Collection no. 1701 was half as tall in 1927 as Minnesota 13 or Longfellow. It was even shorter than *brachytic*, having a height of 103 cm. as compared with 118 cm. for *brachytic*. In the number of leaves, the Persian collections exceeded Minnesota 13 and Longfellow, but were surpassed by *brachytic*, which produced 24 leaves.

As indicated above, a terminal brachyism produces a reduction of plant height by means of a shortening of the internodes, without reducing the number and length of other parts of the plants. It is interesting, in this connection, to compare the average length of internodes of the plants studied by us. Table IV presents the results of the appropriate computations on the data from Kharkov. The figures from this table tell us that the mean internode length in the Persian collections of maize show significant reduction in comparison with the common types. They do not approach the shortness observed in *brachytic* but in any case a deviation from the norm is indicated.

The thickness of the stems of the Persian collections is not only no less, but even somewhat greater than the taller farmer's varieties. All of these characters (shortness of plant, a large number of leaves, and thick stems), considered together, give the impression of a condensation of plant structure, approaching the appearance of *brachytic* in several respects.

TABLE IV

MEAN LENGTH OF INTERNODES IN MAIZE PLANTS, IN CENTIMETERS

	1926	1927
Persian 1701	.....	6.16
Persian 1702	5.35	6.55
Persian 1698	5.11	7.68
Brachytic	.....	4.92
Minnesota 13	9.55	13.2
Longfellow	9.46	13.8

The exsertion of the panicle is perfectly clear from the figures in Table III. At the time during which the distance from the highest leaf to the lower panicle branches was calculated, in Minnesota 13 and Longfellow it was 6–7 cm.; in the Persian collections in 1927, it was 1–3 cm., but in 1926 it did not approach 1 cm., in several instances being even less than zero, that is, the panicle had not completely emerged from the sheath of the upper leaf. In *brachytic* the exsertion of the panicle in 1927 was 1 cm.

Due to the small number of stems, the Persian collections nos. 1701 and 1702 present a characteristically non-bushy aspect, whereas no. 1698 is typified by a significant bushiness. The number of ears per plant of Persian maize is greater than in the types in common culture. In 1927 collection no. 1698 produced an average of 6.3 ears per plant.

Let us continue with a brief glance at the data of the phenological observations (Table V). In the length of the vegetative period the Persian collections present several types earlier than the farmers' varieties. But the essential peculiarity of their differentiation does not lie here. They are distinguished from the common types by their peculiar nature of flowering. As demonstrated in one of our previous

TABLE V

PHENOLOGICAL OBSERVATIONS IN 1927 AT KHARKOV

Collection	Date of seedling emergence	Date of pollination		Silking date		Ripening date
		10%	75%	10%	75%	
Persian 1701	5/27	7/27	8/3	7/25	8/2	9/20
Persian 1702	5/27	7/27	7/31	7/22	7/29	9/20
Persian 1698	5/27	7/27	7/31	7/23	7/31	9/20
Minne. 13	5/26	7/14	7/19	7/14	7/23	9/28
Longfellow	5/31	7/21	7/27	7/23	7/30	9/28

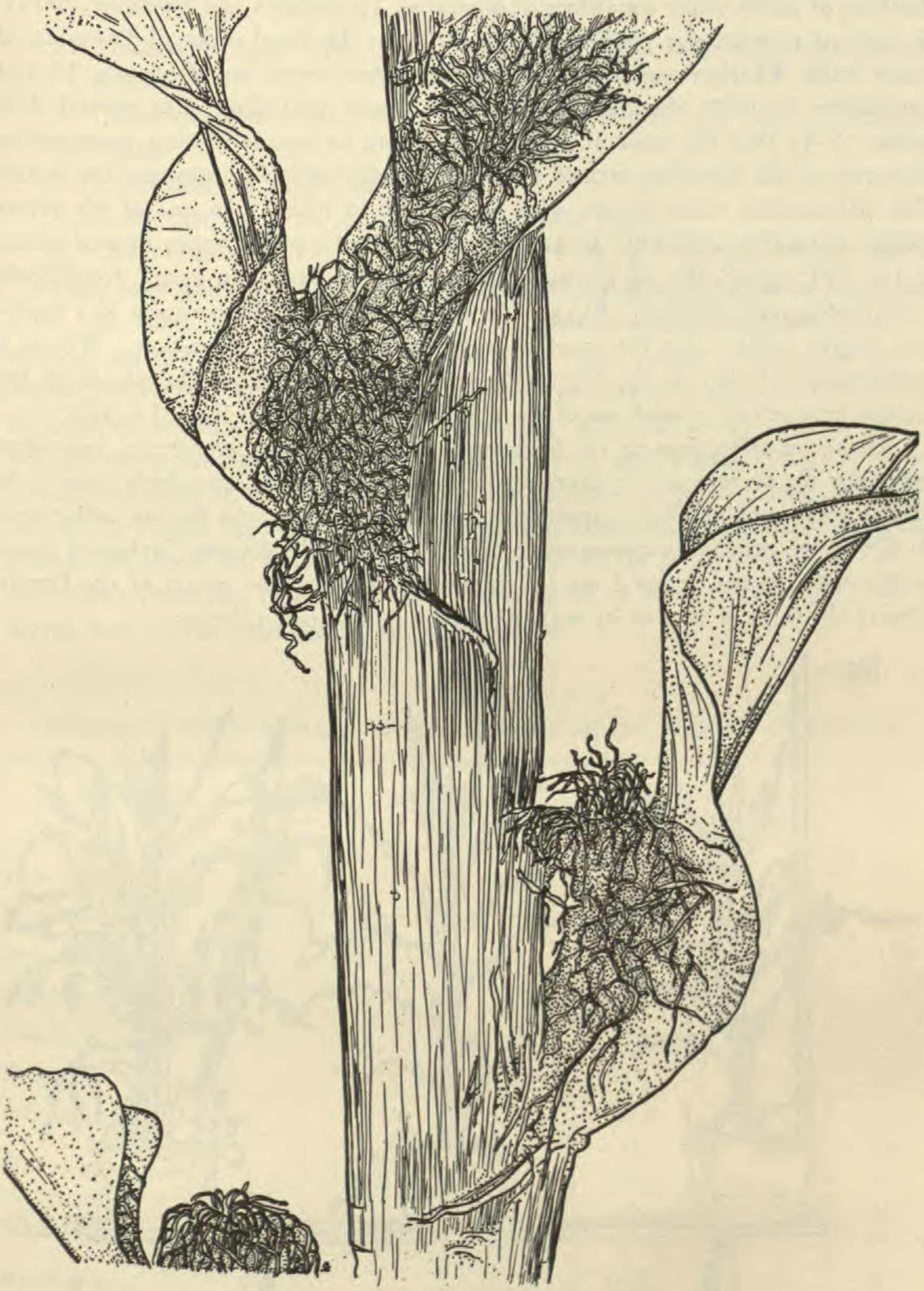

Fig. 6. Concealment of the silk in the axil and sheaf of the leaf in Persian maize, grown in Kharkov, 1927.

works, "the appearance of the silks lags approximately three days behind the shedding of pollen under conditions at Kharkov" (Kuleshova and Kuleshov, 1918). In contrast to what was published by us earlier as the usual order of flowering of maize under Kharkov conditions and to the observations on Minnesota 13 and Longfellow in 1927, the Persian collections began extruding silks several days earlier (2–5) than the onset of pollination, giving an especially clear protogynous character to the flowering instead of the protandry which is common for maize. This phenomenon must be met with very rarely in maize. In one of his papers Collins states that until 1912 he had not encountered a protogynous race of maize, and in 1912 practically all plants from two ears of "red pop corn" from Spain were protogynous (Collins, 1913). He also believes that the presence of a receptive stigma earlier than the onset of pollination aids self-pollination. We see a confirmation of that in the frequently striking uniformity of the plants of the Persian type, which remind one of the uniformity observed in "selfed strains".

Turkestan collections in the field present a fairly large diversity in vegetative type, but the average of this diversity is an array of collections which repeats the general picture of vegetative appearance which is given by the Persian collections. In fig. 8, the principal representative of the vegetatively diverse Turkestan maize is depicted. In nos. 4 and 5 we recognize the characteristic plants of the Persian type in the form of two of its variants—tillering and non-tillering.

Fig. 7. Vegetative diversity of maize plants in Persian collections grown in Kharkov, 1927. Collections Nos. 1701, 1702, and 1698 (from left to right) from Zurabad and Seistan.

The Persian type of plant was established for the following collections:

1. Collection no. 1449 from Mary (Merv).
2. Collections nos. 3434, 3435, 3436, 3437, and 3439 from the Shirabad region.
3. Collections nos. 3450, 3451, 3452, 3453, 3454, and 3455 from the Polotansk region.
4. Collection no. 3425 from Termez.
5. Collection no. 2783 from the Zerevshansk region.
6. Collections nos. 3388, 3389, 3390, 3391 from the Urta-Zerevshansk district.

Nos. 1449 and 3425 share the characteristics of representatives of the Persian type. In Table VI we present several data characterizing these collections. In general, the data from the table are nearly like those which we presented for the Persian collections, which are distinguished by an increased number of leaves and by a shorter vegetative period. These collections do not silk earlier than pollination, but, in some instances, the flowering of the male and female flowers was more closely correlated in 1927 than it was in the common types. An apparent expression of the Persian type was observed in numerous collections from upper Turkestan. Besides the above, we observed different features of the Persian type in a host of collections from the Tashkent region, being expressed now in the stiffness of the leaves, now in the exsertion of the panicles, etc.

TABLE VI

OBSERVATIONS ON TURKESTAN COLLECTIONS IN 1926 AND 1927 AT KHARKOV

	1449 from Merv		3425 from Termez	
	1926	1927	1926	1927
Plant height	88	147	.....	134
Number of leaves	21.0	20.1	.....	19.5
Stem thickness	.....	2.1	.....	2.0
Panicle exsertion	0.0	2.8	.....	2.3*
Number of stems	3.3	3.3	.....	1.2
Number of ears per plant	1.4	5.1	.....	2.2
Date of seedling emergence	5/25	5/27	.....	.....
Date of pollination 10%	7/30	8/6	.....	8/4
Date of pollination 75%	8/8	8/12	.....	8/9
Silking date 10%	8/3	8/5	.....	8/5
Silking date 75%	8/13	8/10	.....	8/9
Ripening date	.....**	10/2	.....	10/2

* [Assumed. Original printing was "23".]

** Failed to ripen before frost.

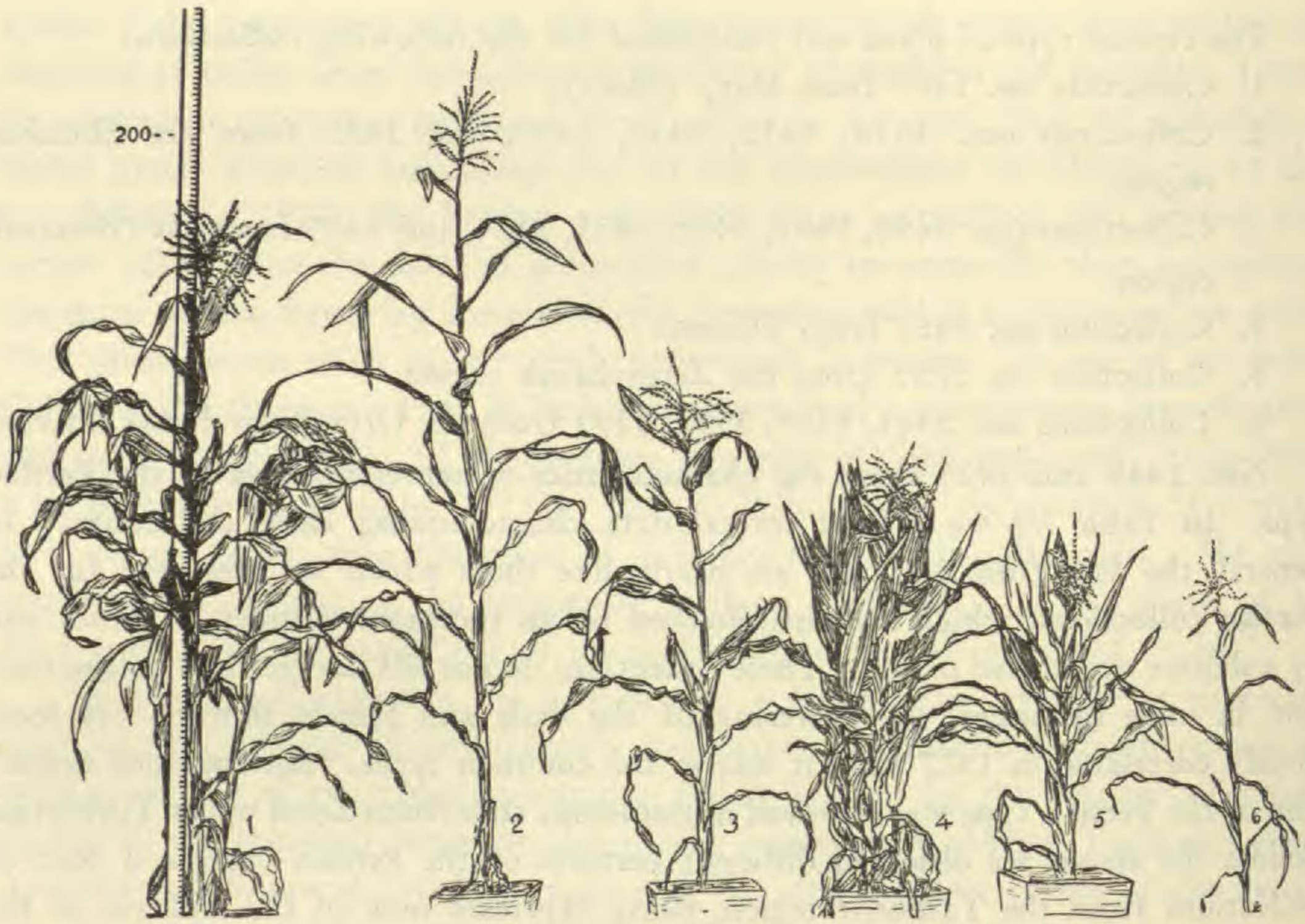

Fig. 8. Vegetative diversity of maize plants in collections from Turkestan grown in Kharkov, 1927. Plants 4 and 5 are from collections 1449 and 3425 from Merv and Termez [respectively].

Fig. 9. Vegetative diversity of maize plants in collections from Armenia grown in Kharkov, 1927. Plant 4 is from collection 1632 from the Echmiadzin District.

In Armenia we also encountered a fairly large amount of vegetative diversity among the collections, the types of which are depicted in fig. 9. Plant no. 3 is distinguished among these plants by its short stature. In its basic features this plant is the same as the "bushy" Persian type, but with several deviations from the typical Persian plants. In the shorter plants of Armenia we observed only free-tillering types. Furthermore, their leaves were usually wider and longer than in the Persian type. In several collections they were significantly longer and had lost their stiffness. In Table VII we present data which are characteristic of the typical short plants from the Echmiadzin region in Armenia.

TABLE VII

OBSERVATIONS ON THE PLANTS IN COLLECTION 1632 FROM ARMENIA GROWN AT KHARKOV

Year	Plant height	Number of leaves	Stem thickness	Number of stems	Panicle exsertion	Ears per plant	Date of seedling emergence	Date of pollination		Silking date		Date ripe
								10%	75%	10%	75%	
1926	82	17.7	....	3.3	0.0	1.36	5/25	7/30	8/8	8/3	8/13	.....*
1927	139	17.2	1.8	3.2	3.9	3.6	6/3	8/2	8/9	8/4	8/12	9/28

* Failed to ripen before frost.

Short plants which were almost exactly as described above were encountered in the following regions:

1. Collections 1625, 1636, and 1649 from the Erivan district.
2. Collections 1619, 1632, 1644, 1647, 1622, 1624, 1638, 1612, and 1705 from the Echmiadzin district.
3. Collections 1616 and 1709 from the Daralagez district.

Besides the collections which are enumerated above, we observed various indications of the Persian influence on collections which were derived from other regions.

TABLE VIII

OBSERVATIONS ON THE PLANTS OF SHORT HABIT FROM AZERBAIJAN, GROWN AT KHARKOV, 1927

Collection	Plant height	Number of leaves	Stem thickness	Number of stems	Panicle exsertion	Ears per plant	Seedling emergence	Date of pollination		Silking date		Ripening date
								10%	75%	10%	75%	
Apsheron 1782	140	20.1	2.7	1.0	2.3	1.5	5/29	7/24	7/31	7/24	7/31	9/20
Nakhichevan 1783	133	16.0	1.2	5.4	....	6.9	5/29	7/31	8/11*	8/2	8/13	10/2

* [Assumed. Originally printed "7/11".]

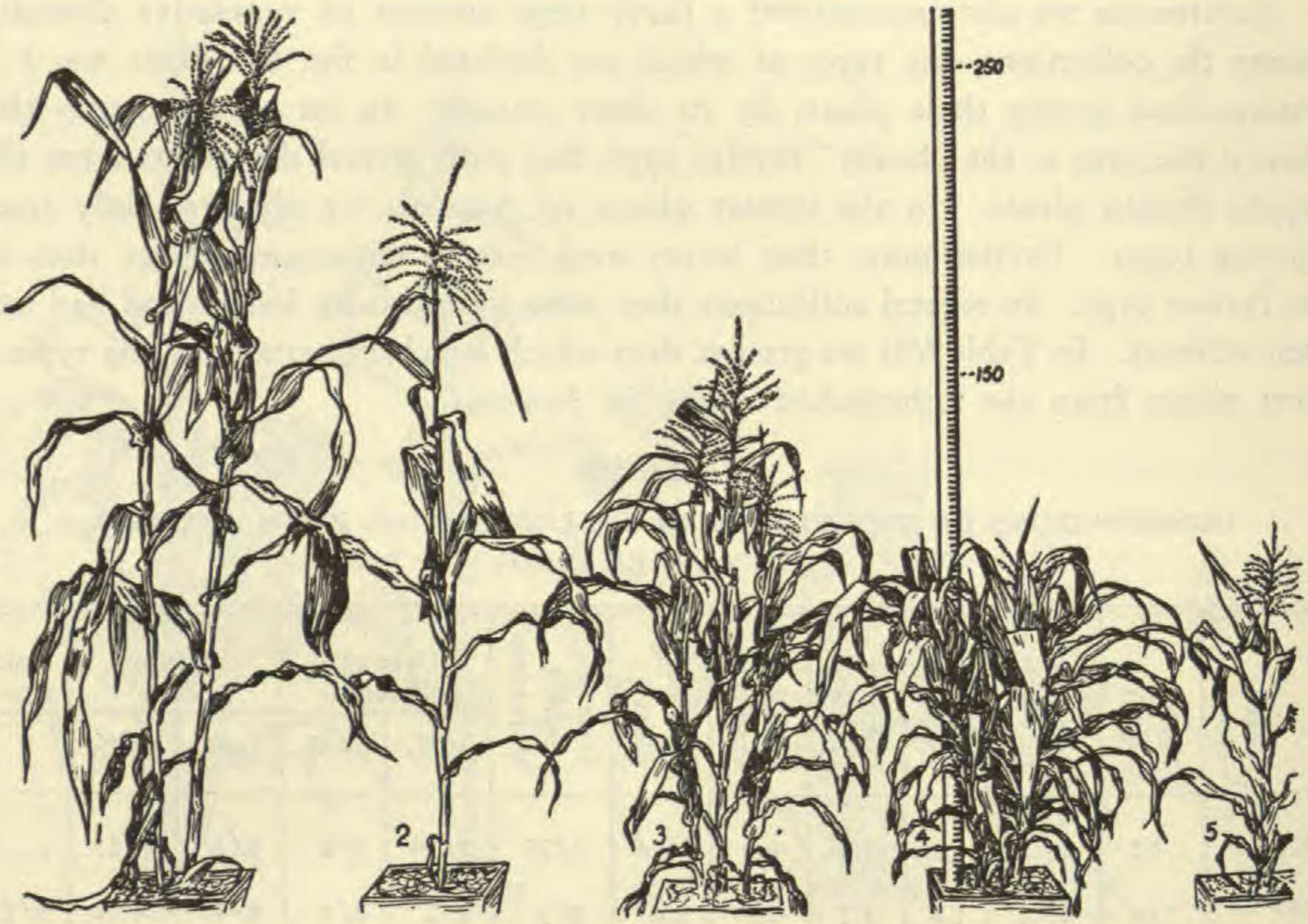

Fig. 10. Vegetative diversity of maize plants in collections from Azerbaijan, grown in Kharkov, 1927. Plants 4 and 5 are from collections 1783 and 1782 from Nakhichevan Rep. and the Apsheron Peninsula.

In Azerbaijan the presence of the non-tillering Persian type was established in collections from the Apsheron Peninsula. In the Nakhichevan region, which borders on Armenia, the variations of the Persian type as described for upper Armenia were seen (fig. 10).

Upon viewing the photograph more attentively, the zig-zag arrangement of the internodes of the plant on the extreme right may be observed. An instance of a similar zig-zag character was observed by Kempton in his studies of *brachytic*, which at once leads to a conjecture of a relationship between our short-stemmed and the well-known brachytic types. Data concerning the characteristics of the short plants which are represented in the photograph are given in Table VIII.

From the data presented, the aspect of the plants from Azerbaijan in comparison with what was stated concerning other regions is sufficiently clear. We wish to mention, however, that in the Apsheron collections we observed a remarkable correlation in male and female flowering time. The studies of the peculiarities of the maize plant which were investigated for the present paper and described under the name of the Persian type give a series of very interesting conclusions:

1. Maize plants short in height considering their normal number of leaves are represented in very widespread regions in central Asia and Transcaucasia.

2. The stiffness of the leaf blades also indicates that the Persian type is very widespread in these regions.

3. The degree to which the upper leaves cover the panicle is quite variable in its expression, indicating a rapid diffusion of the Persian type in the regions of central Asia and Transcaucasia as well as in eastern Asia. Fig. 11 represents the different types of this covering observed in Kharkov in 1927.

4. The concealment of the silking ears is no less widespread in these regions than the characters mentioned above.

We know (through an acquaintance with the work of the American workers) that Collins observed in collections of waxy maize from Shanghai: stiffness of the leaf blades, the panicle covered by the upper leaves, and the concealment of the silking ears. Our data demonstrate a wide distribution of these characters in Asia, as well as their correlation with a definite area. True, in our short plants of the Persian type we do not have that strong expression of brachyism observed by Kempton, but at any rate this shortness compared with normal plants or even with those having a somewhat greater number of leaves gives a basis for comparison with the expression of that character.

The study of the world-wide collection of maize which was conducted in 1926 and 1927 demonstrated that such precise expression of all the recapitulated characters and their delimitation to definite regions will not be observed anywhere else on earth: these extraordinary peculiarities are inherent only to the maize of Asia. The protogynous character of flowering, which is developed so clearly in the Persian collections of maize, is not so widespread in other regions of middle Asia and Transcaucasia. But, at any rate, the remarkable correlation of the timing of male and female flowering can be one of the very characteristic attributes of maize plants in central Asia.

We should still consider one morphological attribute which is frequently encountered in the maize of central Asia and Transcaucasia. This character is the shortening of the stem internodes. There are many exceptions among the described collections and the character may be met with in collections from different regions, but in central Asia it is more often seen than not. In conclusion, after all that has been related concerning the Persian type of maize, we think it necessary to give several geographical and agricultural interpretations of the observed facts. A study of the map [not in the original] of the geographical distribution of the described type of condensed, short plants will show that it is adapted to the driest regions, where agriculture is possible only under irrigation. It is also clear that this type of plant is adapted to the agricultural plains and lowlands. The expedition of the author in 1925, 1926, and in 1927, into Turkestan and Azerbaijan, and the expedition of E. A. Stoletova in 1925 and 1926 into Armenia completely and definitely attest to this fact.

In those regions in which the presence of the Persian type of maize was established, the maize fields are usually of very small area, since these regions are known to be essentially limited to the culture of cotton. Maize is here grown on the edges of cotton fields or as a kitchen-garden crop. The biological and agricultural description of the plant and the extraordinary adaptation of this crop plant to the diverse

conditions of the region of its cultivation were of great interest. Its shortness and its condensed structure are very valuable characters for regions of irrigation, giving a plant steadiness against the wind and protecting it from lodging on softened irrigated soil (see Kempton, 1921). The nearness of the leaves to each other, as effected by the shortness of the stem internodes, causes them to shade one another, by which, apparently, a reduction of transpiration is obtained. The stiffness of the leaf blades, oriented parallel to the sun's rays and not perpendicular to them, represents a broad adaptation in the plant kingdom without excessive insulation of the leaf in hot dry areas. The rough cutinized leaf which, unfortunately, was not studied anatomically, may also be considered an adaptation for reducing transpiration.

In 1927 during the journey to the Iolotansk Experiment Station in Turkmenistan, which is located on the edge of the burning waterless desert of Karakum, we chanced to see burned areas on the leaves of the American variety of maize in the variety observation plots. The burning was caused by the hot dry winds "garmsil", which are peculiar to the central Asian regions. In the local collections there were no similar burns. The panicles are covered by the stiff upper leaves and the silking ears are hidden in the axils and sheaths of the leaves. Thus these delicate flowering organs are protected from the destructive action of the dry burning winds of the Asian desert.

The simultaneous appearance of the male and female flowers, facilitating the timely utilization of the pollen, must be recognized as very expedient under the conditions of central Asia, for in the dry hot air the flowers and pollen of maize cannot be abundant, nor can the germinating pollen grains.

According to their reports, the American investigators consider the character *brachytic* to be very important, especially for dry regions, and are working towards a combination of the productiveness of normal types of maize with the shortness

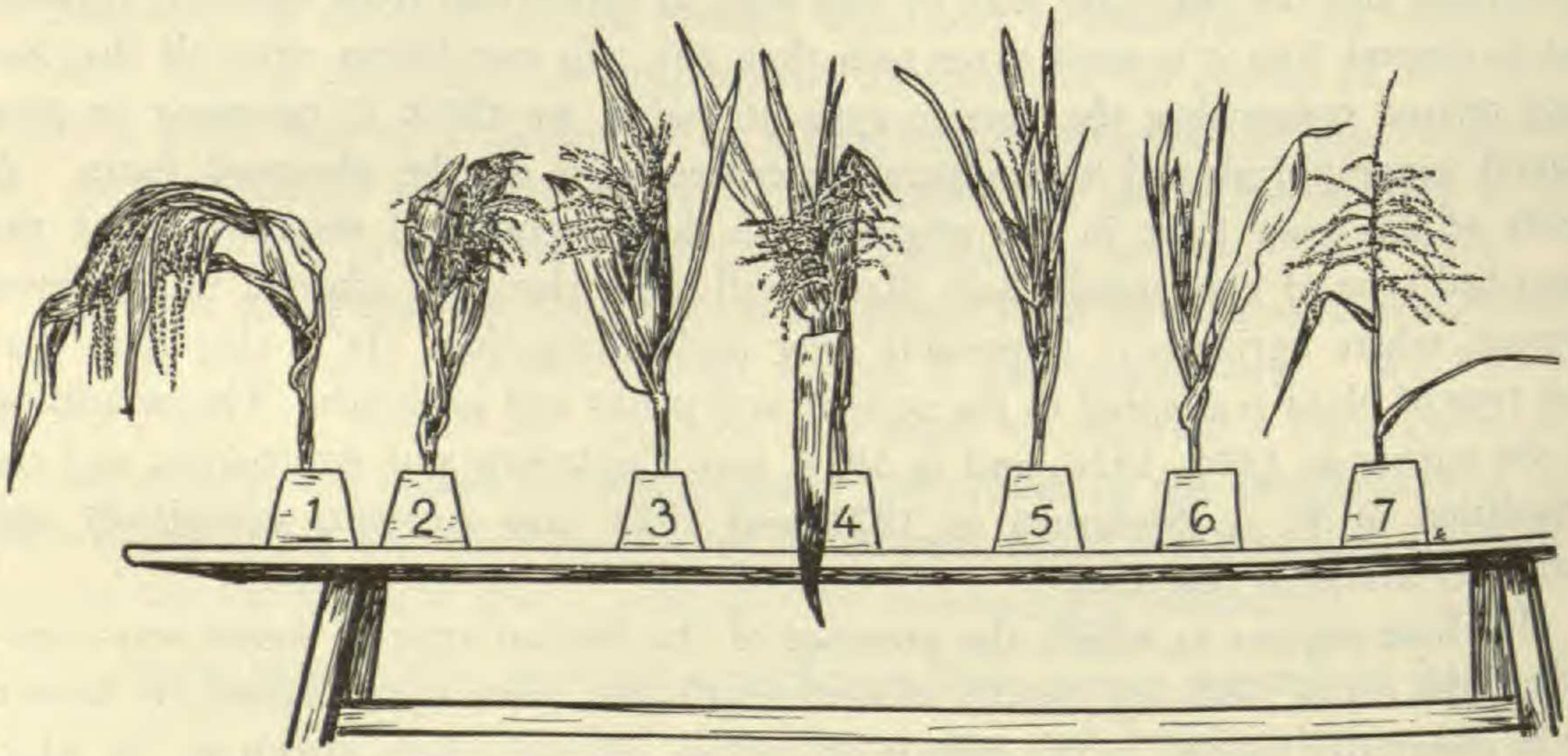

Fig. 11. Different types of covering of the panicle by the upper leaves. Plants 1 and 2, Primorskiĭ Province; 3–6, Persia and Turkestan; 7, common open panicle. Kharkov, 1927.

of *brachytic*. In the collections described as the Persian type we have an undoubted approach to the resolution of this problem in that we have an entire array of other characters for the final stages of the important selection work to find a drought-resistant type of maize.

3. CONVERGENCE IN THE VEGETATIVE APPEARANCE OF THE PLANTS OF MAIZE AND SORGO ORIGINATING FROM THE SAME REGIONS OF ASIA

A great variety of crops which originated from widely different parts of the world were planted in 1927 at the Ukrainian Station of the Institute near Kharkov. These plants demonstrated that the place of geographical origin of many crops is mirrored in the array of general vegetative characters, notwithstanding the fact that they are classified in widely differing species, genera, and families. For example, the lucernes, flaxes, and wheats of north Africa are distinguished by a very intensive growth and differentiation in the early stages following germination. Flax, peas, and wheats from central Asia have a definite tendency toward dwarfness and slow growth in a number of collections. The lucerne of Turkestan has, in comparison with the lucernes of other regions, short internodes, slow growth, etc. Apparently, the ecological conditions which have been imposed on these crops in the current century have influenced them to the production of a general ecotype, the one most successfully responding to the conditions of the region.

While we were conducting a detailed study of a large collection of maize and sorgo in 1927 at the Ukrainian station of the Institute, in cooperation with V. I. Savron and A. I. Ivanov, we noted that a striking analogy was manifest in the aspect of the plants of maize and sorgo from the same regions of Asia. In the preceding section we described in detail, under the name *the Persian type*, a special type of maize which was distinguished by shortness in height and internodes. Maize, which is a new plant on the Asian continent, changed its aspect in central Asia in the very same direction as the oldest crops—flax, lucerne, etc. In the sorgo stocks A. I. Ivanov noted plants among the Turkestan collections which were distinguished by the very same short stems and broad leaves as were previously described for maize of the Persian type (fig. 12).

During our expedition to Turkestan in 1927, in cooperation with I. V. Gduzenko, we observed a striking resemblance in vegetative aspect between the plants of maize and sorghum in the field. In this respect the Geoktepe region of Turkmenistan is especially interesting. The very same short height was seen in sorghum in fields of the Shirabude Experiment Station near Bokhara. This dwarf sorghum is considerably less widely distributed in Turkestan than the common tall type, but we discovered it, nevertheless, in many places, in many regions (Geoktepe, Archman, Termez, Merv, etc.). In these same regions and places we almost always discovered the dwarf, condensed Persian type of maize plants.

In other regions of Asia—Manchuria, northern China, and the Primorskiĭ Province—there was also a striking resemblance in vegetative aspect between maize and sorgo which originated from the same region. Plots of maize and sorgo are

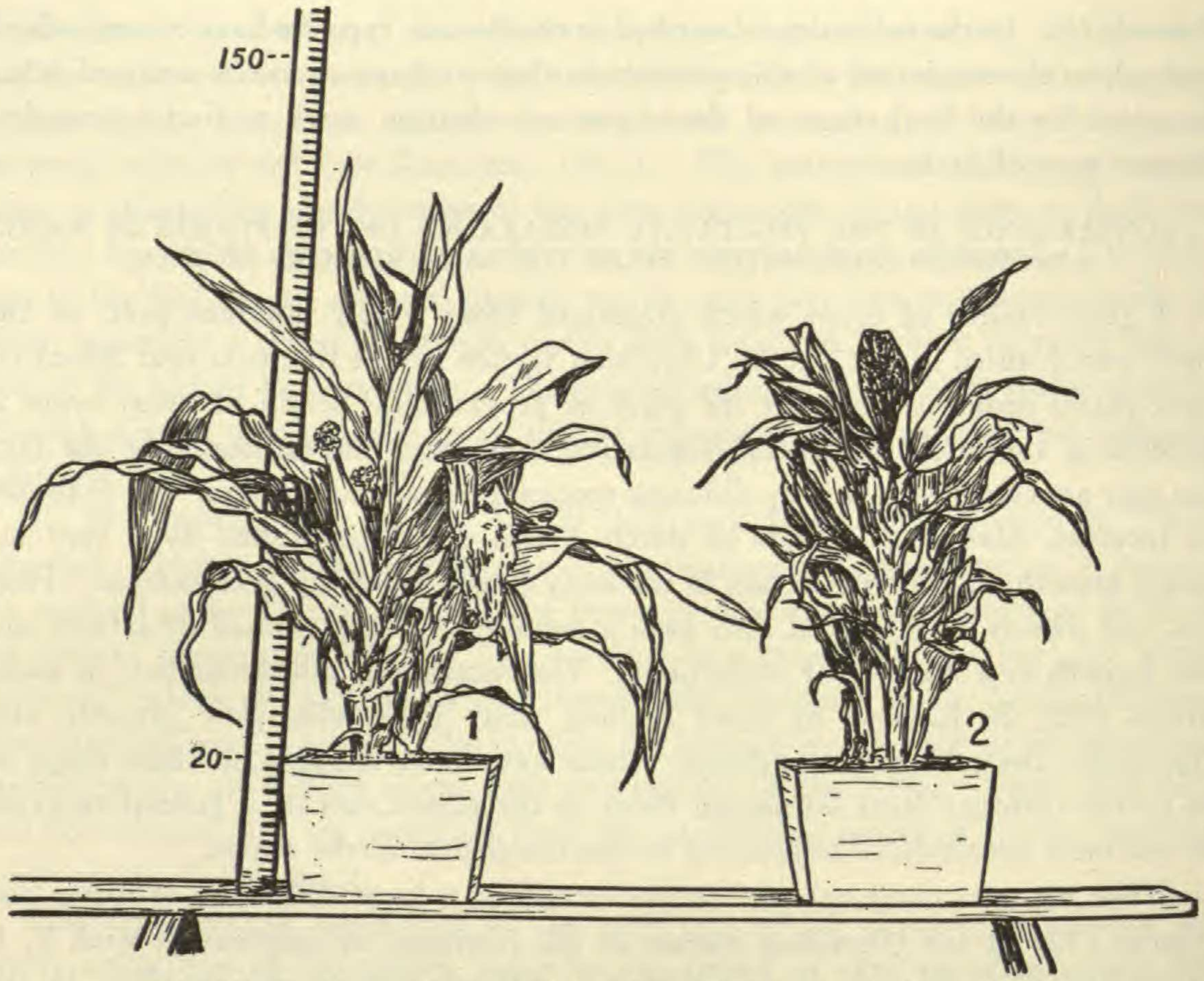

Fig. 12. Sorghum and maize plants of short habit, from Bokhara, 1927.

already quite striking in appearance at the 9–10-leaf stage, being sufficiently distinguished by tall plants with thin stems, long basal internodes, and a palm-like arrangement of their long, narrow leaves at the apex (fig. 13). These plots all contained plants from Manchuria, northern China, and the Primorskiĭ Province. Further observations showed that, besides sorgo and maize, the same plant structure may be observed in plots of *Panicum italicum* from the same regions.

Upon further development the similarity between these plants is not diminished: Manchurian Kaoliang resembles Manchurian and Primorskiĭ maize, and Manchurian and Primorskiĭ maize are similar in aspect to Kaoliang. Figure 14 represents maize and sorgo from central and eastern Asia, photographed after flowering. The similarity is striking. In these two regions sorgo and maize are so similar in external aspects that an inexperienced observer recognized sorghum plants of these regions by their outward aspect without difficulty, after once seeing our plots of the peculiar maize of central and eastern Asia. In addition to the illustration, we present measurements of the internodes of the plants which were photographed, numbering the internodes from bottom to top (Table IX).

The data presented here corroborate well what was stated in the text and demonstrated in the illustrations. The facts which have been studied in this section lead involuntarily toward the raising of several general questions of the biology and variation of plants. For instance, *Andropogon sorghum* presents an Asiatic

TABLE IX

INTERNODE LENGTHS (IN CM.) IN PLANTS OF SORGHUM AND MAIZE IN FIG. 15, GROWN AT KHARKOV, 1927

Number of internodes	Sorghum Bokhara	Maize Termez	Manchuria	
			Sorghum	Maize
1	2.0	2.0	4.0	6.0
2	2.5	3.5	11.0	8.0
3	3.75	4.0	21.0	8.5
4	3.75	6.5	27.5	20.0
5	4.0	3.25	24.5	22.5
6	4.5	5.5	24.5	19.0
7	4.0	4.0	27.0	21.0
8	4.0	3.3	29.5	18.5
			(to panicle)	
9	5.0	5.0	49.5	18.0
10	5.0	4.5		
11	5.0	10.0		
12	5.0	9.0		
	(to panicle)			
13	15.0	8.0		
14		2.0		
15		1.5		
16		8.0		
(to panicle)		(to panicle)		
17		9.0		

aspect, having been known to be in culture in Asia for more than 3,000 years. Also maize, according to the present view, could not have been introduced into Asia earlier than 1516, when the Portugese ships first touched the China shores. Thus, 400 years is the maximum time which, on the basis of the literature, can be assumed for the cultivation of maize in Asia. In an evolutionary sense it is impossible to consider 400 years a long time, but meanwhile, during these 400 years, maize, which is foreign to the Asiatic continent, attained an aspect similar to that of the oldest crop plant in Asia—sorgo. On the basis of these observations we must assume either a very high plasticity for the maize plant, or conversely, that maize was introduced into Asia earlier than 1516. Unfortunately, due to insufficient data, the latter is an impossible assumption.

4. LIGULELESS MAIZE

A peculiar condition of leaves which lack a ligule at the juncture of the leaf sheath and the blade has been described in cereals by several authors. Nilsson-Ehle observed it in oats; N. I. Vavilov discovered liguleless type of rye and wheat in Pamir; K. A. Flaxberger established the presence of liguleless wheats in collections from the island of Cyprus (Flaxberger, 1926). Liguleless maize was described by Emerson (1912). Liguleless plants were discovered by him in 1910 in the progeny

Fig. 13. Similarity of plant habit in sorghum, maize, and *Panicum italicum* from Manchuria, in the 9- to 11-leaf stage. [From left to right]: maize, *P. italicum*, sorghum. Kharkov, 1927.

of a self-pollinated plant which was grown from a single ear with tooth-like kernels which was brought from the National Corn Show in Omaha. A closer inspection of the leaves of the *liguleless* plants showed that, besides the reduction of the ligule (which in several leaves is retained although in a very rudimentary form), the auricles, by which the vertical position of the leaves and their clasping of the stem is actually accomplished, are also absent.

A genetical investigation of the character *liguleless* demonstrated that it is recessive and in hybrids segregates in a ratio of 3:1. As fas as we know, no one besides Emerson has studied the character of ligulelessness in maize. In 1927 at Kharkov in our plots, V. I. Savron and I discovered ligulelessness in plants of maize in three cases:

Fig. 14. Convergence in vegetative habit of maize and sorghum from central and eastern Asia. Center, a plant of *P. italicum* from Manchuria. Kharkov, 1927.

1. *Collection no. 2773 from the village of Seraphimovok, the Vladivostok district in the Primorskiĭ Province, referred to the group everta.* Among 20 plants of a plot, in 11 the leaves on different stems were marked by a reduction of the ligules from complete absence to its retention as a rudiment as compared with the normal aspect. The auricles were absent from the leaves. In fig. 16 this original plant type is depicted.

2. *Collection no. 2746 from the village of Novopokrovok, in the Spassk district, the Primorskiĭ Province.* Of 22 plants only one was liguleless, but the ligulelessness was very well developed.

3. *Collection no. 1419, originating from the Caucasus (unfortunately without a more exact notation as to place, and doubtful as to origin).* Of four plants, one was typical liguleless.

Liguleless plants were not discovered in any other collections either at Sukhum or Kharkov, notwithstanding the fact that the collection was world-wide. Also, in general, no one has established ligulelessness before in open-pollinated collections of maize under natural conditions of development. Our findings appear to be peculiar in their class and the maize of Asia is of new interest.

Collections nos. 2773 and 2746 were received from the Primorskiĭ Province the first of the year 1927, and were first seeded in 1927. The origin of collection no. 1419 is not certain, but the original seed of it was used for sowing.

Fig. 15. Maize and sorghum stems with the leaf sheaths removed, from Bokhara and Manchuria. Kharkov, 1927.

Fig. 16. Liguleless plant in collection 2773 from the Primorskiĭ Province, near Vladivostok. Kharkov, 1927.

III. General Conclusions Concerning the Maize of Asia

In the preceding section, on the basis of data from the literature and from our own investigations, we arrived at the conclusion that in the maizes of Asia we have observed an array of characters and peculiarities which are unknown in America, or which are extremely rare in America. At any rate, we observed these characters, not in occasional isolated instances but often and associated with definite and frequently large areas. Therefore, waxy endosperm has a wide distribution in eastern Asia from 5–45° north latitude; dwarf plants are peculiar to vast areas of central Asia; while the sheltering of the panicles by the upper leaves and the concealment of the silking ears in the leaf sheaths are encountered in eastern and central Asia, Transcaucasia, etc.

These facts indicate that in Asia several conditions contribute to the production of new types of this plant which is known to be American. However, when we

appraise more closely the characters which are peculiar to the maizes of Asia or discovered in them, we should, on the basis of the data from the literature, meet recessiveness in most of them. Thus waxy endosperm, *brachytic* dwarfness of the plant habit, and ligulelessness are recessive.

In 1927 N. I. Vavilov published a very interesting work on the geographical regularity in the distribution of genes of the crop plants. In the words of N. I. Vavilov: "The basic centers of diversity of types are the sources of diversity which are characterized not only by the presence of a large number of types, but, what is no less important, by the presence of a large number of dominant factors. Conversely, the secondary centers of diversity are characterized by a diversity principally of recessive factors."

From this viewpoint concerning the maize of Asia we undoubtedly have a secondary center of diversity, and our Asiatic material gives satisfactory facts for the corroboration of the views of N. I. Vavilov. At the present time no one doubts the American origin of maize (Messedaglia, 1924; Weatherwax, 1923) [And a reference to a non-existent sixteenth item in his *literature cited*], and the Asian maize is of course viewed as an introduction.

This assertion by no means hinders the raising of another exceedingly interesting question, and this question concerns the time of introduction of maize into Asia. At present we have no documentary evidence which would indicate that maize was known in Asia before Columbus [A reference to a non-existent seventeenth citation]. But the striking facts which are described in the present paper inevitably lead to the idea that Asian maize, if it be not viewed as native, at any rate is very ancient. These characters, which were seen in Asiatic maize, attest to this explanation. As we saw, waxy endosperm, which was discovered in Asiatic maize, was also discovered in the most ancient crop of Asia—sorgo. Dwarfness, which is characteristic of Asiatic maize, is also characteristic of sorgo, flax, and other ancient crops. But these characters are found in large areas, and for them to be manifest in maize, time, of course, is required.

If we agree with Collins, we must assume that waxy endosperm arose in the maizes of Asia by means of mutation and has its place of origin in upper Burma, which is largely populated by wild tribes with whom even today it is almost impossible for aliens to have intercourse. Now, concerning the time interval in question, we must understand when and how maize could have been removed from America into this isolated wild land, given there a mutation and as a mutant diffused from the Philippines to northern Manchuria. The answers we can not give, of course, with certainty, but as a conjecture we should suppose that likely there was an earlier cultivation of maize in Asia than the time of the first landing by the Portugese on the shores of Asia in 1516. A similar conjecture was expressed in one of his papers by Collins (1909), but subsequently he retracted it. The facts, which were established by us, return us anew to this supposition and this time with a great deal of conviction.

We have already dwelt upon the agricultural and biological significance of these characters which were described for Asian maize. Their value as to suitability to the exceptionally dry conditions of central Asia is undoubted, and therefore Asiatic maize arouses a very great interest regarding plant breeders' aims. The character *waxy* is no less interesting from the practical point of view. The exceptional capacity of waxy endosperm to be hydrolyzed by the diastase enzyme has been explained according to the most recent investigations of Americans. In comparison with other types of endosperm, the hydrolysis of waxy endosperm is more rapid in several cases [Reference to literature citation 18].

This condition leads one to suppose an increasing adoption of the products prepared from waxy maize in the diet of the natives. We do not yet know the suitable experiments, and we know nothing about the conduction of plant-breeding experiments with waxy maize, but both [questions] arouse very great interest.

Rapid-growing races of waxy maize from the Primorskiĭ Province and northern Manchuria ripened fully under the conditions of Kharkov, and subsequently in almost the entire maize-growing region of the USSR.

The present communication represents in part the large cooperative work on the investigation of maize and sorgo which is being conducted by the author in cooperation with I. V. Kozhukhov, M. I. Hajinov, V. I. Savron, A. I. Ivanov, and E. S. Yakushevskii at the All-Union Institute of Applied Botany. We must also mention the exceptional aid which was rendered by the section of M. G. Tsyup in photographing the most interesting plants. We express also our deep gratitude to all the institutions and persons who responded to the requests of the section and sent to the Institute collections which served in a large part as material for the present paper.

Leningrad.

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